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How Close to Reality is the „as-is” Business Process Simulation Model?

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Background and Purpose: Business process simulation (BPS) model is based on real-life data form sources like databases, observations and interviews. It acts as “as-is” business scenario can used for reengineering. The main challenge is to gather relevant data and to develop simulation model. Research aims to elaborate BPS model and to systematically assess how close to reality it is.
Design/Methodology/Approach: The research has been performed in Polish telecommunications company. Authors investigate technical process of expanding cellular network. After elaborating “as-is” model, authors use ADONIS simulation tool to run a series simulations and confront simulation results with actual historical events. After this, assessment whether computer simulation model can precisely map real-life business process – and consequently act as credible basis for process improvement – is made.
Results: The simulation model has been constructed with data from the WfMS database, observations, staff knowledge and their experience. Fully equipped simulation model is found to allow reconstructing the historical execution of business activity with low margin for error. Some limitation were identified and discussed.
Conclusion: BPS is not a popular approach for process reengineering and improvement yet. Data collection issues for BPS that require adopting process mining techniques and additional information sources are among the reasons for that. In our study, computer simulation outputs are compatible with historical events. Hence the model reflects the business reality and can be taken as a reference model while redesigning the process.

Keywords: *business process, business process simulations, data acquisition, workflow systems*

1 Introduction

Business Process Management (BPM) is an attention-attracting topic for management staff, enterprise modeling communities and scientists. BPM framework supports the design, enactment, control, analysis and improvement of business processes. The procedure has been designated by E.C. Deming and W. Shewhart as the PDCA method (Moen and Norman, 2009). The PDCA method can be used as a basis for practical solutions that are developed by business software vendors for supporting complex business processes management. Finally, the business process management cycle has been enriched by business process simulation (BPS) phase. This stage is usually supported by an IT simulation tools and is an important part of the evaluation of (re)designed processes (Tarumi, Matsuyama and Kambayashi, 1999; Suzuki et al., 2013).

Computer simulations of business processes apply to both newly created processes and processes that are already in operation in commercial environments (Workflow Management Coalition, 2013). In the former case – design time analysis (Van der Aalst, Weijters and Maruster, 2004), simulation is mostly focused on examining abstract steady state situations called “to-be” scenarios, which is helpful for initial design for business processes but is still less suitable for operational business process execution (Rozinat et al., 2008).

So, the a-priori simulation model consists of theoretical inputs, such as the shape of business process model, organizational structure and some parameters including activity costs and duration times as well as decision point probabilities, resources availability, etc. Because analysts have direct access to all mentioned theoretical inputs, they can explore different contrived scenarios with respect to the theoretical effect. In the latter simulation case – run-time analysis (Van der Aalst, Weijters and Maruster, 2004)

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business process has been commercially executed for a long time and this enactment is supported by information systems – Workflow Management Systems (WfMS).

Usually, WfMS engine performs the workflow logic based on an implemented process model. Every commercial execution of the process model is called business process instance. WfMS performs process instances and, simultaneously, archives sets of information in a database (Gawin, 2009). Thus, produced event logs usually contain data about cases (process instances) that have actually been executed in an organization. Event logs record the times at which tasks were executed, the persons or systems that performed the task and other kinds of data. Such logs are the starting point for process mining (Van der Aalst, Weijters and Maruster, 2004) which means discovering knowledge about processes and discovering data that can power simulation models.

While powering data comes from the workflow management system database, the simulation model reflects the "as-is" situation (Rozinat et al., 2008). One of the main challenges is to create simulation models that accurately reflect the real-world business process executions. For the "as-is" situation, both the simulated and real-world process should overlap as much as possible.

The real business continuously needs process improvements to achieve better performance (e.g., better response times, less costs, higher service levels) (Van der Aalst, 2010). By modifying real parameters and performing various scenarios of simulations, analysts can estimate business results of the process time requirements and costing, staffing needs to be established, the identification of bottlenecks as well as calculation of resource loads, with which the company intends to carry out the process. With the use of simulation, the (re)designed processes can be evaluated and compared. Simulation provides quantitative estimates of the impact that a process design is likely to have on process performance, and so a quantitatively supported choice for the best design can be made (Jansen-Vullers and Netjes, 2006). The most popular information tools for business process modeling and simulation include ARIS, ADONIS and iGrafx, but the simulation experience is still limited. Some organizations – e.g. Wipro (Srivastava, 2010), Qwest (Teubner, McNabb and Levitt, 2008), Slovenian Ministries (Jaklic and Stemberger, 2005) and Motor Company (Hauser, 2007) provide case studies of projects involving simulation tools and a number of these projects have proved successful.

This paper seeks to identify, systemize and elaborate implementable techniques of preparing a business process model based on the historical data, which truly reflects the real process behavior. The remaining part of this paper is organized as follows. Section 2 overviews related work on business process simulation types, tools and process mining techniques. Business case study along with research process is presented in section 3. Section 4 discusses data inputs for business process assessment and powering business process simulation model. In section 5 authors execute multi-instance business process simulation to compare simulation results with historical process outputs. Research is discussed in section 6, followed by conclusions.

2 Related Work

2.1 Business Process Simulation on PDCA Cycle

Business process simulation integrates seamlessly with the PDCA cycle and can be performed in two stages: between process modeling (*Plan*) and execution (*Do*), as well as between process revision (*Check*) and practical improvement (*Act*). Figure 1 illustrates the proposal of PDCA cycle extension with BPS (Business Process Simulation) actions. Output of the PDCA Plan stage allows abstracting real business needs and representing them in graphical or/and

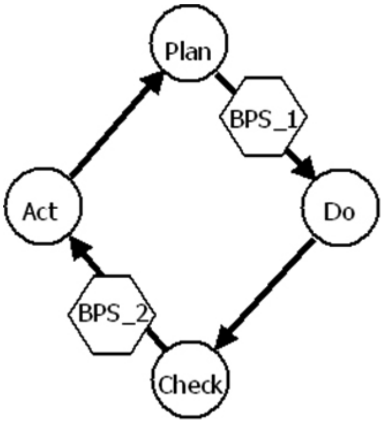

Figure 1. Extended PDCA cycle

descriptive form (Becker, Kugeler and Rosemann, 2003). The most popular visual notations include BPMN (Object Management Group, 2013), eEPC (Scheer, 1992), IDEF3 (Mayer et al., 1995) and UML Profile for Business Modeling (Johnston, 2004).

To perform the first BPS action (described as *BPS_1*), the graphic model must be enhanced with quantifiable data. At this stage, *BPS_1* aims to achieve the vision and estimated values (Workflow Management Coalition, 2013) of the business process, which means theoretical (pre-execution) process costs, execution times, resource utilization, etc. In the process implementation/execution stage (*Do*), the business process is enacted on WfMS and outcomes are recorded in a database to be analyzed in the succeeding phase (*Check*). In the latter, experts, analysts and managers review executed processes and evaluate them with regard to strategy. They operate on real data – historical execution values (Workflow Management Coalition, 2013) from WfMS database and consider also comments from process participants. Collected data and information power the "as-is" simulation model (stage *BPS_2*) to "catch the reality" in digital form. By defining KPIs and creating business cases, analysts and managers identify the requirements to create and implement enhanced processes (post-execution optimization). But, before commercial launch of corrected workflows, the *BPS_2* stage allows many "what-if" simulation scenarios which reflect planning business reality based on real historical data.

BPS can be shown as a simple function: $y=f(x)$, where function f presents a model that transforms inputs x to the result (output of that model) y (Bosilj-Vuksic, Ceric and Hlupic, 2007). By entering different x values, function f generates different y results and can be considered as "what-if" simulations. Another way is to conduct "what-if" optimizations by setting a target value for y, then searching for the values of x that result in the target value for y. Simulation allows to capture process dynamics and helps to investigate random variable influence on process development.

Process simulation could play an important role in supporting business process change management approaches such as TQM, Just-in-Time, Business Process Re-engineering, Process Innovation and Knowledge Management (see Hlupic and Vreede, 2005). In this context, simulation can be used to investigate knowledge management processes, to simulate missing data needed for knowledge management, or to evaluate alternative models of knowledge management strategies.

Simulation is used to describe a broad range of capabilities. These involve reproducing or projecting the behavior of a modeled system (Barnett, 2003). Models for simulation can be classified based on system of interest: a physical system (e.g. supply chain or production line), a management system (e.g. CRM or workflow process) or a meta-model (e.g. rules that establish whether a model is formulated properly).

In 2013, Workflow Management Coalition (WfMC) has published Business Process Simulation Specification (BPSim) (Workflow Management Coalition, 2013). Authors stress how important it is to simulate and analyze business processes in a safe isolated environment before they are deployed and identify reasons for simulation and analysis still not being systematically used in most process improvement projects. Lack of mature standards for BPS in contrast to standards for simple process modeling is pointed out as the main reason. Framework BPSim introduces a standardized specification that allows process models to be augmented with data in support of rigorous methods of simulations and analysis. Provided meta-model is captured using UML and supports both pre-execution and post execution simulations.

2.2 Process Simulation Types and Tool Support

The main idea of business process simulation is to execute the model repeatedly to reflect the real business behavior. Contemporary IT literature distinguishes two types of BPS (Russell et al., 2005; Van der Aalst, 2010): Transient analysis and Steady-state analysis. In the former case, answers for operational questions (i.e. times, costs and probabilities predictions) in the near future are provided. When the transient analysis starts with initiated (and still not completed) process instances, then the model takes into account queues of work and temporary resources unavailability. For steady state, the initial state is irrelevant – the simulation model resets any cases in progress and it takes time to fill the system with tasks. Steady state is relevant for answering strategic and tactical questions rather than predicting the near future.

Simulation types have become a practical rather than theoretical domain. Software vendors provide copyrighted simulation algorithms that differ regarding parameterization. Generally, process-oriented software falls into three types of tools (Jansen-Vullers and Netjes, 2006): business process modeling tools, business process management tools (BPM) and BPS tools. The former enable creating multidimensional process models in one or more available notations. As a result, static reports can be generated for process documentation, manuals, instructions, functional specifications. BPM systems can be perceived as tools that support managing business processes across the whole PDCA life-cycle (i.e. FLOWer).

The core part of BPM system is workflow engine. BPM is defined as supporting business processes using methods, techniques and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information (Van der Aalst, Ter Hofstede and Weske, 2003).

BPS tools support for process measurement and simulation, based on diverse techniques and providing broad range of outputs. BPS practitioners appreciate modeling flexibility, animations and simulations effects, statistical capabilities, variety of output reports and how user-friendly a simulation tool is. (Bradley et al., 1995) propose seven different categories to evaluate BPS tools, i.e. general capabilities, hardware and software features, documentation, user-friendliness, modeling-oriented potential, simulation capabilities as well as output analysis capabilities.

2.3 Process Mining and “as-is” Simulation Model

With reference to Figure 1, it can be said that in case of *BPS_1* analysts need fictive inputs, mostly needed by business simulation model to design and predict future behavior. While performing *BPS_2*, they need a simulation model which captures historical process shape and parameters, because “as-is” simulation models should reflect the reality as strictly as possible. In order to obtain useful simulation model to perform different process scenarios, process mining techniques extracting relevant data regarding processes from WfMS database are often used.

WfMS operates with Business Process Participants in a client-server architecture, where the client side is usually a web browser (rarely a separate application) that can be operated from the employee’s device. Based on the process definitions, workflow engine executes process models as flows of forms and documents that contain information regarding the tasks for employees. The aforementioned forms – Transaction Sets – are managed in accordance with defined routes. In commercial use, dedicated business processes are initiated on the engine several times, but based upon a single process definition. Running the same process numerous times means that workflow systems sequentially record process instances in the database. Process instances, recorded over the years in the event log, contain a huge amount of workflow data. Exploration of the data, also known as Knowledge Discovery in Databases, is a multi-step process that involves raw data transformation from the event log into actionable knowledge about the organization. In addition to the actual projection of the company’s operations, the data may also be used to feed the simulation-oriented computer process models.

The process mining method involves discovering knowledge about business processes, which are, by nature, dynamic phenomena. Business process analyses are reasonable provided that observations refer to attribute values not at specific moments, but over a long term. The discovery process involves the transformation of raw data into useful information which is used at a later stage to improve the systems and processes. The most valuable knowledge on organizations involves the hidden patterns, rules, trends and correlations in data structures, which are formed automatically over a long time period during data archiving in database systems. Discovery of these non-trivial relationships between attributes provides unique insight into the operation of the company, inaccessible using less refined methods of assessing business processes (Van der Aalst, 2007).

Workflow mining algorithms allow detailed analysis to be carried out, taking into account four perspectives, each dedicated to discovering different aspects of process-related knowledge: Control Flow Perspective, Organizational Perspective, Case-Related Information Perspective as well as Conformance Checking Perspective (see Business Data Collection and Process Analysis section). Results provided feed analysis stage (*Check*), process simulations (*BPS_2*) and process definitions improvement (*Act*) to achieve improved workflow definitions.

3 Case Study

3.1 Business Domain Description

The case study involves the workflow system which supports execution of business processes in the telecommunications organization in Poland. The investigated company provides mobile telecommunications services (voice, data transfer, internet) across the whole country and its internal structure is divided into four regions: Maritime, Mountainous, East and West. The analyzed case study was performed in one of them (Maritime Region). The investigated database comes from the workflow Action Request System (ARS) provided by BMC Software company from Houston (USA, Texas).

The workflow ARS tool has been collecting instances of business processes since 2002. Because of big volume of recorded data in database, the event log investigated in our research reflects one-year activity. The instances concern the following business areas: planning, building and operating mobile telecommunication network and our case study concerns an event log which reflects three types of workflow processes:

1. *Parameters Changing*: setting telecommunication devices parameters, e.g.: transmitted radio frequency, radio transmission power, number of available voice channels;
2. *Order Advice*: transmission network modifications like radio link tuning, light pipe building and testing, equipment software updates, redirecting antennas;
3. *Planed Work of Base Transceiver Stations*: activities that require commercial service interruption to perform necessary modifications.

Investigated processes relate to planning, operating and maintaining telecommunication services and physical infrastructure. All of them have been originated by personnel responsible for planning the telecommunication network and then executed by teams responsible for network operation and maintenance.

Workflow instances flow between two departments: *Planning Department* and *Executing Department*. Workflows can also take place between teams within the department. Table 1 introduces data regarding teams of employees, which are involved in planning, building and maintaining telecommunication network.

Relevant workflows can proceed according to different scenarios: employees of *GPST_1* can take decisions regarding the need for extension/modification of the telecommunication network. Then, depending on the set of tasks, projects can be expanded (by *GPST_2*) with more data, or can be passed directly to *Executing Department*, where projects are run and implemented. Both the employees involved in the preparation of projects and in their implementation can take advantage of specialized tools, which are usually purchased from suppliers of telecommunications equipment. Employees also use IT, measurement equipment and service cars to perform site surveys. During the flow of work, the employee uses workflow system to obtain information, documents and work description to perform assigned tasks. After completing contracted work, people forward process instance to another contractor. If the worker performs the last step of the process, then the process initiator checks the implementation of project and after this completes a particular instance of the process in workflow system.

3.2 Research Description

Our research aims to elaborate guidelines which can help to answer the question how close to reality is the “as-is” computer simulation model. To develop our approach we use process mining – which enables discovering knowledge about processes, evaluating discovered information and powering the simulation model with data. We extend reality assessment by observations based on business process simulations (*BPS_2* included in extended PDCA cycle). After performing simulations (*BPS_2*) we indicate some additional techniques that help compare simulation process model with the real business process execution.

The idea of business process management (BPM) provides continuous improvement of business processes, but this cycle requires useful simulations on models which capture the real business processes. In this paper, we skipped details regarding process mining algorithms, focusing on process mining results that can help assess the reality of discovered data. We also do not discuss the details of simulation algorithms. Both topics have been addressed in previous work (Gawin, 2009; Gawin and Marcinkowski, 2013; Marcinkowski and Gawin, 2014). Figure 2 overviews line of research.

Research process involves a recurrent cycle, which, like the Deming wheel, provides for the continuous monitoring and improvement of business processes in companies. *Workflow Management System* is based on theoretical models of business processes and coordinates the execution of these processes in the enterprise. Process instances are recorded in the database and contain attributes reflecting the actual information regarding performed activities. These data include identifiers of personnel involved, durations of activities, invoked external applications and options selected in decision-making that influence the further course of the process instance. The database distinguishes subsequent instances by a unique number allocated by the workflow system on process instance start.

Table 1: Technical departments and teams involved in the execution of business processes

Department	Technical team	Abbrev.	Responsibilities
Planning Department	Design_team_1	GPST_1	Estimating the deployment of telecommunications equipment in the field (base stations locations) and telecommunication equipment parameterization (base stations transmitting capacity, radio signals frequency etc.)
	Design_team_2	GPST_2	Estimating the deployment of transmission telecommunication equipment in the field, (locations of radio lines, fiber optic), transmission parametrization (radio link transmission power, optical line attenuation etc.) and setting core parameters (e.g. for Mobile Switching Exchange)
Executing Department	Maintenance_team_1	GUST_1	Implementing telecommunication projects (especially BTS part)
	Maintenance_team_2	GUST_2	Implementing telecommunication projects (especially transmission part)
	Maintenance team_3	GUST_3	Implementing telecommunication projects (especially core part)

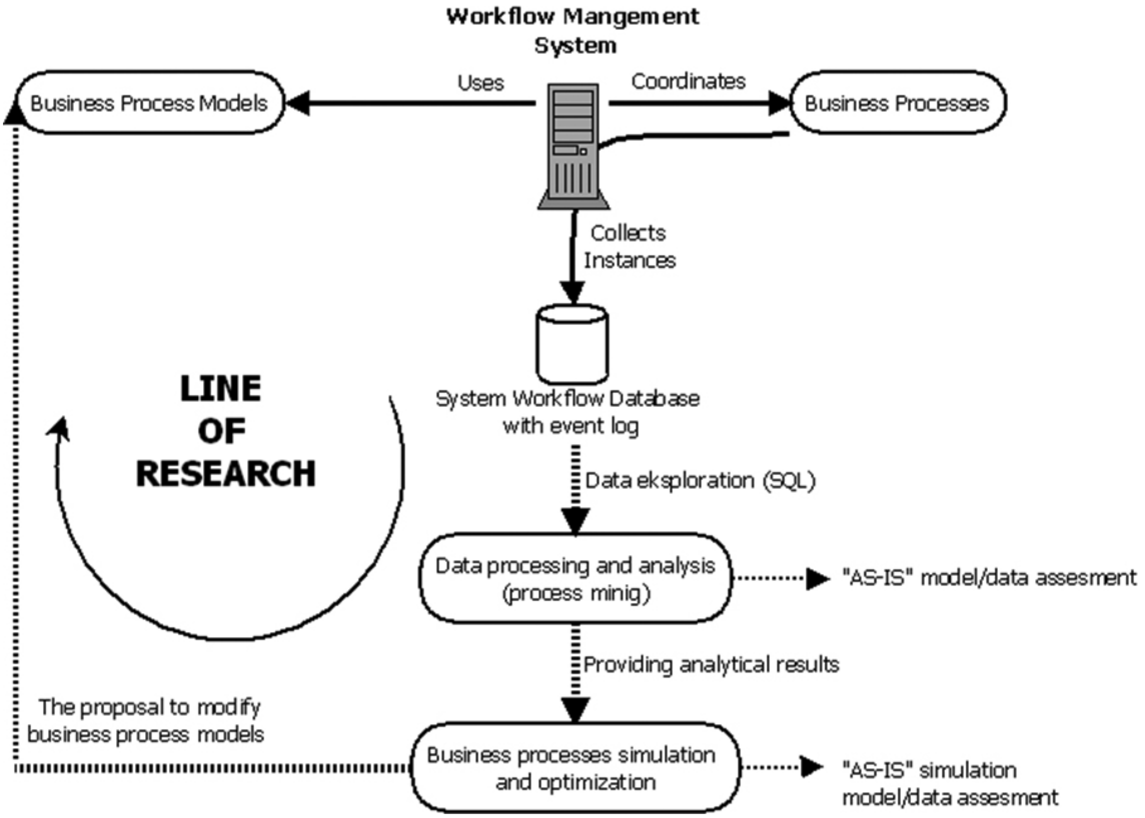

Figure 2. Line of research

Table 2: Data from workflow database

Discovered data	Data type	Data source	Additional information
Graphical model of the business process	Processed data	Workflow mining – Control Flow Perspective	Based on hierarchically stored phases of each process instance, workflow mining algorithms reconstruct graphical process model
Organizational structure	Processed data	Workflow mining – Organizational Perspective	Workflow mining algorithms analyze database and discover who and how many times performed process activities
Time-related parameters	Raw data	Basic statistic	Basic statistic provides information how long every activity and every process instance has been historically executed; min., max and average statistics are available as well
Number of business process occurrences within the chosen time period	Raw data	Basic statistic	Number of occurrences comes directly from SQL query, limited to a specific period of time
Probabilities for outgoing workflows from decision points	Raw data	Basic statistic	Probabilities comes as a mathematical quotient of all running instances with respect to those affected by the selected path

Research begins with the *Data exploration* stage. At this stage process instances are explored from workflow management database. Then, we analyze them with process mining techniques which come from Eindhoven University of Technology. For this purpose, ProM (Process Miner) IT tool is used. Subsequently, we analyze mining results in different perspectives and assess how close to reality the discovered information is. Based on mining results, we construct an "as-is" simulation model for selected business process. Without any model transformation, we execute the "as-is" simulations to verify whether results might be helpful in assessing the reality of computer model.

Business process simulation models allow to perform some process scenarios that enable us to predict the future behavior in a company. Simulation results can enable introducing changes in business process definitions (Figure 2: *Business process simulation and optimization* and then *The proposal to modify business process models*). In our research, further simulations involving modifying business process parameters were performed, yet remain out of the current paper's scope.

3.3 Data Collection Methods

Simulation of business processes requires a process model interrelated with additional models (e.g. organizational structure) as well as powered with data regarding durations, costs, path probabilities etc. Most models and parameters can be discovered from the WfMS database, but some of them come from the "people knowledge" about the organization. A set of data to be collected depends on simulation tool, which shall execute "as-is" simulation model. Market investigation and evaluations led to selecting ADONIS Process Management tool provided by BOC. Research involved collecting data both from WfMS and from process participants.

3.3.1 Data exploration from WfMS database

The workflow system records all events in the event log, from which the complete history of the process can be reconstructed. Seeking to achieve "as-is" simulation model for one of the available telecommunications company processes, the authors identify data and knowledge from database singled out in Table 2.

All aforementioned data can be discovered WfMS database with ProM tool. Before performing analysis, data should be imported from database and transformed into the acceptable by ProM file format (see Figure 3).

Required information regarding instances are transferred to MXML format using four intermediate Microsoft Access tables. MXML file contains many process instances and its attributes and enables performing workflow mining analysis to reconstruct the process model, as well as the organizational model of organization (Gunther and Van der Aalst, 2006). Raw data comes as ProM Basic Statistic and do not require any additional actions. Processed data are subjected to process mining algorithms, what leads to constructing business process simulation model.

3.3.2 Data exploration from personnel knowledge

BPS_2 specificity (see Figure 1) requires additional information that cannot be collected from WfMS. Some of them are mandatory (as mandatory inputs for simulation algorithms), and some help to understand people's behavior and business rules in the company. Table 3 includes information that should be obtained from process participants along with techniques that may be used to obtain the information.

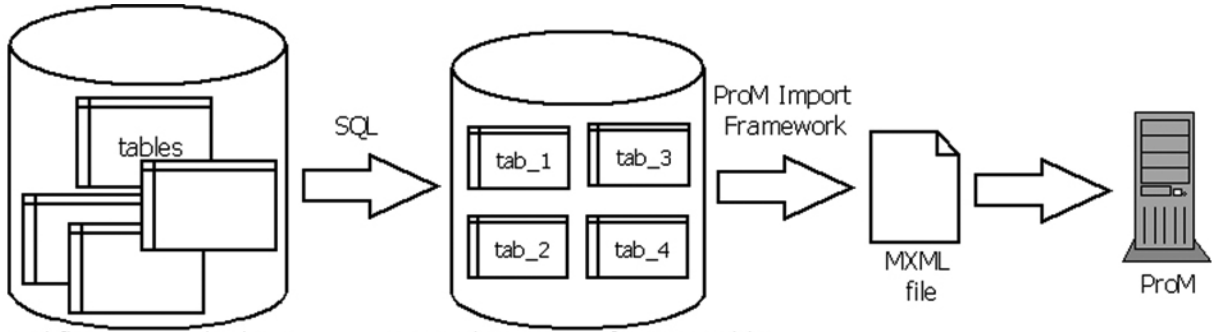

Figure 3: Simulation data preparation

Table 3: Information regarding business process and company provided by staff

Information	Collection technique
Business process description from employees' point of view	observations, interviews
Official business process model and business activity description	official documentation analysis, interviews
Actual organizational structure	official documentation analysis
Availability of staff	individual management interviews
Number of hours per working day	individual management interviews / official documentation analysis
Number of working days per year	individual management interviews / official documentation analysis

Official documentation provides general overview of business processes. Additional documents include information regarding organizational structure, including "tree view" of departments, teams and employees along with full names and organizational roles.

Generally, observation enables business analysts to access information that are not provided by any class of IT in a company. Elimination of intermediate links in the process of data collection which may contribute to increases in the probability of misinterpretations may be regarded as an advantage of observation. Research carried out involved combining diverse range of observation types (see Gray, 2013). Authors participated in business processes and observed rather non-controlled employees' behavior. Additionally, not all employees were aware of research conducted. Knowledge obtained with the technique enabled supplementing workflow management system with data regarding phone calls, mails and meetings, leading to executing process instances as best as possible.

Research process involved performing interviews with management staff. Interviews are a practical alternative to observation as a method of collecting data without the use of IT support. They involve approaching respondents with more or less formal questions within a particular issue area. Interviews boiled down to the reciprocal flow of information and may be carried out using different procedures (see Sztumski, 2010). Researchers were allowed to perform face-to-face, unstructured interviews with management staff – rather groups than individual. It contributed to good understanding of actual business process instances in telecommunication company, ability to interpret research results properly and identify potential areas for optimization.

4 Business Data Collection and Process Analysis

4.1 Control Flow Perspective

To achieve transparent results, the event log from the investigated WfMS database has been limited to a single business process – *Order Advice*. Because of a considerable volume of process instances stored, an additional filter was included to investigate cases limited to a single year. The initial workflow mining analysis – control flow perspective of a process – establishes interdependencies among activities. The goal of mining the perspective is to provide a visual, diagram-oriented presentation of all possible process instances historically executed. From a business point of view, managers responsible for workflow processes in an organization can review reconstructed diagrams and answer certain questions: How are the cases actually being executed? Are there any parallel executions? Are there any loops? What is the process model that summarizes the flow followed by cases in the log?

ProM supports various plugins to mine the control flow perspective of process models. From available algorithms, three techniques were tested: Fuzzy Miner (Gunther and Van der Aalst, 2007), Alpha (Medeiros et al., 2004) and Heuristic Miner (Van der Aalst et al., 2007). Finally the latter one was selected due to the fact Heuristic Miner algorithm can deal with noise and incompleteness of event log. Additionally, the algorithm has options to focus on the main process paths instead of attempting to model the complete details of the behavior reported in the event log as well as wide parametrization capabilities.

Heuristic net for *Order Advice* process (Figure 4) visualizes the reconstructed model that includes all the 71 instances (superposed). Every rectangle denotes a process activity and incoming/outgoing transitions indicate flow of work. Activities are assigned activities descriptions, identifiers of organizational groups responsible for execution,

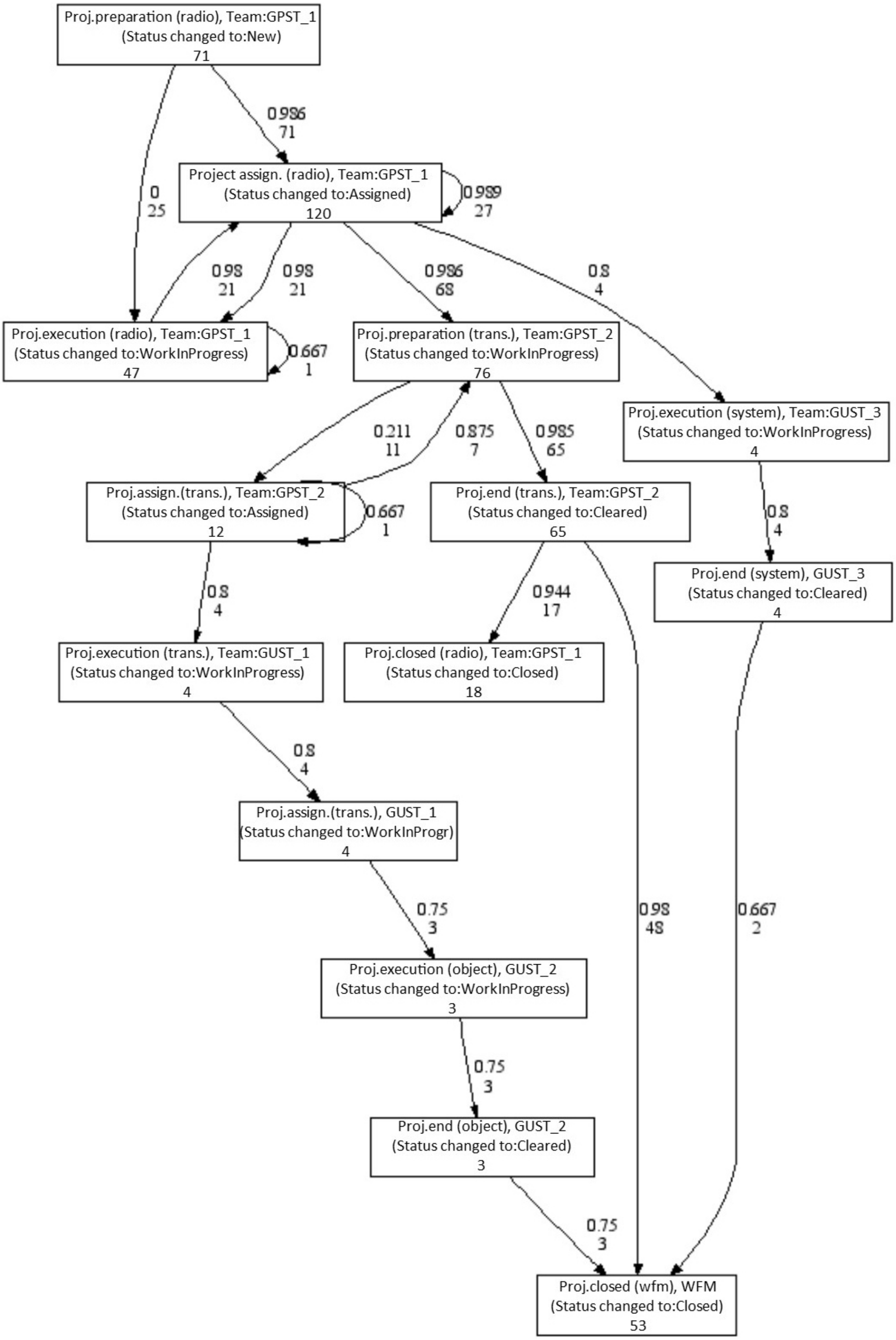

Figure 4: Heuristic diagram of business process Order Advice.

activity status changes as well as the number of times the activity was performed.

Both WfMS documentation and employees' statements confirmed that workflow system did not support parallel workflow executions, so multiple outgoing transitions from a single activity denote alternative flows. From the business point of view, lack of parallel paths caused numerous organizational issues during the process execution. To synchronize some parallel activities, employees used mails, phone conversations and meetings – what caused numerous relevant data to be processed outside the WfMS. The first decimal value assigned to transitions between activities indicates certainty level regarding existence of direct dependency between two activities. The value is always between -1 (not really sure) and 1 (completely sure). The second value provides information regarding number of flows through the transition between activities that were identified.

The Heuristic Miner algorithm also enables testing the discovered process model. The result can be assess with the continuous semantics fitness (CSF) parameter. Based on discovered model, CSF algorithm parses actual process instance from the WfMS. Should any instance not precisely fit the model, algorithm indicates an error and continues processing. Errors correspond to Heuristic Miner discovery issues, especially in case the event log recorded noise, uncompleted instances and complex flows. The maximum value of CSF is 1 and indicates that model discovered from database 100% fits to instances from event log. In our case, the result of the parsing provided CSF value of 0,964 – Heuristic Miner coped well with the events log and almost perfectly mapped the instances from database into the visual model.

4.2 Organizational Perspective

The process data can also be examined from an organizational perspective. It was the ProM Social Network Miner algorithm (Van der Aalst, Reijers and Song, 2005) that was found the most attractive for discovery of social network. The algorithm enables employee-oriented analysis; managers can observe who is mostly transferring work to whom, as well as who mostly begins, who ends the instances and how the work flows among performers.

The organizational perspective provides also additional research that classifies people in terms of activities performed and organizational units. Organizational Miner (Song and Van der Aalst, 2008) is responsible for discovering and automatically grouping people carrying out similar tasks. Mined groups should coincide with the real organizational units from telecommunication company. Table 4 includes discovered organizational structure and activity assignment for *Order Advice* business process.

Table 4 data indicates that in a single calendar year 19 people participated in 71 instances of business process. Employees executed a total of 897 process steps arranged into 14 coherent activities (ACT numbers from 1 to 14). Total number of process steps, in which employees were engaged and the percentage of employees' engagement in the execution of process steps were included as well. For the purposes of this study, the real names of the process participants were encrypted in ORIG.nr form. Based on the interviews with the staff, we have confirmed that the Organizational Miner algorithm properly organized employees into groups (based on similar tasks) as well as accurately assigned employees to activities – the matching was flawless.

4.3 Other Data Collection

4.3.1 Basic simulation inputs

The ADONIS Process Management tool selected to support research process provides the following types of simulations: times and costs, accounting analysis, path analysis, capacity analysis as well as workload analysis (incorporating both steady state view and fixed time period) (more BOC Group, 2013). Each simulation algorithm needs some basic set of input data that allows initiate simulation scenarios. Table 5 summarizes the parameters required to carry out the simulations. The suggested technique of collecting values for the individual parameters was specified in each case; the upper part of the table lists the inputs that can be extracted from the workflow system database, while the lower part contains the data to be collected using other, non-IT techniques for gathering information about processes.

Activity execution time, during which the current activity is executed, can be provided for every process step from ProM tool as basic statistic information. Alternatively, the metric might be extracted from Case-Related Information Perspective. Research is based on average activity execution times form ProM basic statistic across 71 process instances. Similarly, *number of instances within the chosen time period* can be reached in both ways. Also *probabilities of initiating individual outflows of decision points* come from ProM tool and enable assigning transition probabilities to all connectors leaving decision points (XOR logic). The sum of all transitions probabilities of the connectors equals 1.

Cost parameters are considered optional for simulation and collecting them can be challenging in practice. *Number of hours per working day* serves in combination with the value in the field *number of working days per year*, in which instance can be executed. Process and staff calendars aren't taken into account in the capacity analysis algorithm that was used in research. *Availability of staff* specifies whether a performer works full-time or part-time in the business process. This parameter takes the value between 0 and 100% - the latter indicates full engagement in

Table 4: Organizational structure and task assignment for business process Order Advice

No.	Employee identity	Organizational group identified by the algorithm	Performed activity identifier	Actual organizational group	Participation in the process	
					Quantity	%
1	ORIG.0	minedGroup0	1,2,10	GPST_1	289	32.22%
2	ORIG.2	minedGroup4	8,4,9	GPST_2	156	17.39%
3	ORIG.3	minedGroup4	8,4,9	GPST_2	80	8.92%
4	ORIG.1	minedGroup0	1,2,3,10	GPST_1	69	7.69%
5	ORIG.7	minedGroup0	1,2,3	GPST_1	68	7.58%
6	ORIG.9	minedGroup4	8,4,9	GPST_2	62	6.91%
7	ORIG.4	minedGroup5	7	SYSTEM	53	5.91%
8	ORIG.5	minedGroup0	2,3	GPST_1	40	4.46%
9	ORIG.8	minedGroup0	2,3	GPST_1	20	2.23%
10	ORIG.11	minedGroup2	13,14	GUST_2	12	1.34%
11	ORIG.6	minedGroup3	5,6	GUST_3	12	1.34%
12	ORIG.14	minedGroup4	8,4	GPST_2	8	0.89%
13	ORIG.10	minedGroup1	11,12	GUST_1	4	0.45%
14	ORIG.12	minedGroup1	11,12	GUST_1	4	0.45%
15	ORIG.13	minedGroup3	5,6	GUST_3	4	0.45%
16	ORIG.15	minedGroup1	11,12	GUST_1	4	0.45%
17	ORIG.16	minedGroup0	2,3	GPST_1	4	0.45%
18	ORIG.17	minedGroup1	11,12	GUST_1	4	0.45%
19	ORIG.18	minedGroup0	2,3	GPST_1	4	0.45%
Sum	-				897	100%

a single business process without any out-of-the-process activities.

Capacity analysis algorithm enables simulation business processes while taking into account the corresponding working environment. That leads to the observation of workloads within the current organizational structure. Also the total execution time of all instances can be observed. Should the simulation model be based on reliable process behavior – as well as accurate organizational structure and other set of parameters (see Table 5) – then the simulation results reflect business scenarios that occurred in the past. So, results of capacity analysis can be taken into account while assessing the reality of "as-is" business process simulation model.

4.3.2 Algorithm parametrization

Tuning-in the capacity analysis algorithm to meet research goals requires providing additional statistic from databases as well as some information from process participants (see Table 6). First parameter, *Number of instances within the chosen time period*, can be fed directly from heuristic diagram of business process, as it is assigned to initiating activity during mining process (see Figure 4). Special consideration should be given to *Availability of staff*, as assessing the value of the parameter proven a challenging task for management being interviewed. Consensus was met at 20% level. Regarding the *Number of simulation*, increasing the value of parameter improves the accuracy of the results while increasing the simulating device's CPU load. Value of 1000 allowed running simulations without significant delays.

Participant-related information for simulation model are summarized in Tables 7 and 8. Please note that some activities in Table 7 – *ACT_2, ACT_8*, *ACT_12* – have no human resources assigned. This is due to incorrect WfMS deployment in the investigated company; the aforementioned activities represent periods of time when instances were awaiting next process participant (scheduled to perform succeeding activities in the process instance). Nowa-

Table 5: Data inputs for various simulation algorithms

Algorithm	Time and costs	Analytical evaluation	Path analysis	Capacity analysis	Workload analysis		Technique suggested for collecting data
Inputs					Steady state	Fixed time period	
Business process model	X	X	X	X	X	X	Process mining (Control Flow Perspective)
Working environment model	–	–	–	X	X	X	Process mining (Organizational Perspective)
Activity execution time	X	X	X	X	X	X	Process mining (Case-Related Information Perspective) or basic statistic
Number of instances within the chosen time period	–	–	–	X	–	–	Process mining or basic statistic
Probabilities of initiating individual outflows of decision points	X	X	X	X	X	X	Process mining (Case-Related Information Perspective)
Cost indicators (per activity)	X (opt)	X (opt)	X (opt)	X (opt)	X (opt)	X (opt)	Interview / Observation
Cost indicators (per performer)	–	–	–	X (opt)	X (opt)	X (opt)	Interview / Observation
Number of hours per working day	X	X	X	X	–	–	Interview / Observation
Number of working days per year	X	X	X	X	–	–	Interview / Observation
Process instance initiation calendars	–	–	–	–	X	X	Interview / Observation
Performers' calendars	–	–	–	–	X	X	Interview / Observation
Availability of staff	–	–	–	X	–	–	Interview / Observation
Number of simulations	X	–	X	X	X	X	Scientist decision

Table 6: Additional parametrization

Parameter	Value
Number of instances within the chosen time period	71/year
Number of hours per working day	8
Number of working days per year	260
Availability of staff	20% (for every employee)
Number of simulations	1000

days, WfMS do not allow for designing waiting periods as separate activities – the system should monitor and store time between activities as transition attributes to estimate bottlenecks in the process instead. *Total number of employees in the group* comes from general knowledge of the process and determines the maximum number of resources of a given organizational unit (which theoretically can be involved in the implementation of business process execution). *Number of people involved in the process* is determined based on organizational perspective, while *Avg. execution time* may be established in process mining research as well as ProM basic statistics.

Table 8 provides more detailed information from WfMS database that refer to the historical performance of the business process execution. Data include number of times each participant took part in the execution of a process step (see organizational perspective). Both summarized metrics and summaries excluding activities with no resources assigned are provided. Some differences between values provided in Tables 4 and 8 can be observed.

While both refer to the same phenomena – number of tasks performed by employees – task assignment in Table 4 captures how many times employees recorded beginning/ending individual tasks by clicking start/stop buttons in the WfMS. Data in Table 8 reflects how many times employees actually participated in activities. Some activities involved one-click records (*ACT_1*, *ACT_7*, *ACT_10*) because this activities relate to the initiating/concluding the whole process instance. Remaining activities involved two-click records – at the beginning and at the end of the single activity. Process simulation algorithm accepts only the actual participations in the process.

Aside from personnel, in many cases company IT is also engaged in performing certain activities. In telecommunication company, it was WfMS (codename *ORIG.4*) that performed *ACT_7* as many as 53 times – the latter being a codename for closing the process instance (see Table 8). Cause for that was violating some business rules by employees from GPST_1 team – after completing the process, the person who initiated instance should verify whether ordered work was done correctly. After verification, the same person should close the processes instance. Since instances were rarely close manually, WfMS automatically concluded them after two weeks.

4.3.3 Construction of simulation model

After collecting information regarding *Order Advice* business process, target simulation model is to be built. The control flow perspective provided a business process model which was adopted for ADONIS. Additional data – from organizational perspective/ProM basic statistics/personnel knowledge – enabled constructing fully parameterized simulation model and tuning it in to perform capacity analysis. Figure 5 illustrates heuristic net that was redrawn to ADONIS process model.

Activities *ACT_2*, *ACT_8*, *ACT_12* representing waiting times for undertaking next activity in the process are modeled as notes indicating the place of their placement. The aforementioned activities are correctly implemented as additional time parameters for adjacent activities. So, the execution time of *ACT_2* is entered as resting time for *ACT_1*, while *ACT_8 ACT_12* are represented respectively as waiting and resting time for *ACT_11*. Teams involved in the business process are modeled as pools. In accordance with Tables 4 and 8, each process activity was assigned dedicated resources as non-notational properties, which simulation algorithm can use for simulating process activities executions.

5 Business Process Simulation to Achieve “as-is” State

After preparing a business process simulation model, the simulation was performed with capacity analysis algorithm. Simulation has been initiated as 71 process instances in accordance with explored data. Output generated by the simulation tool for aforementioned number of instances included total execution time of *01:071:21:30:18*. Thus, business process simulation results may be interpreted as follows: executing the process 71 times requires a total of 1 year, 71 days, 21 hours, 30 minutes and 18 seconds.

The result is an approximation of the historical executions of this process. To verify simulation results, actual initiation time of the first instance – that took place at 10:39, 20XX-02-12 – was explored from WfMS database. The end of the last instance has been recorded next year - on 3:15, 20XY-02-12. Based on real-life data from WfMS database it can be concluded that the actual delivery time for 71 process instances was 365 days. So, the difference between the simulation result and information from WfMS database is approximately 70 days.

Table 9 outlines ADONIS simulation results that relate to the employees’ involvement in the execution of each activity. The comparative analysis of simulation results (Table 9) against actual historical data (Table 8) allows to address the question whether simulation results of the business process coincide with the results that have been developed historically in the real-life implementation of the process.

Table 7: Values of process activities' attributes

Activity	Proj. preparation (radio)	Project assign. (radio)	Proj. execution (radio)	Proj. preparation (trans.)	Proj. execution (system)	Proj.end (system)	Proj. closed (wfm)	Proj. assign. (trans.)	Proj.end (trans.)	Proj. closed (radio)	Proj. execution (trans.)	Proj. assign. (trans.)	Proj. execution (object)	Proj.end (object)
Identifier	ACT_1	ACT_2	ACT_3	ACT_4	ACT_5	ACT_6	ACT_7	ACT_8	ACT_9	ACT_10	ACT_11	ACT_12	ACT_13	ACT_14
Responsible organizational group	GPST_1	-	GPST_1	GPST_2	GUST_3	GUST_3	WfMS	-	GPST_2	GPST_1	GUST_1	-	GUST_2	GUST_2
Total number of people in the group	7	-	7	6	9	9	1	-	6	7	6	-	13	13
Number of people involved in process	3	-	6	4	2	2	1	-	3	2	4	-	1	1
Avg. execution time dd:hh:mm:ss	00:00:02:36	10:03:38:49	00:00:09:19	03:09:25:37	00:00:23:25	09:12:06:19	00:00:00:00	02:00:14:00	13:07:22:22	00:00:00:00	00:00:26:22	104:03:03:5	00:00:00:48	14:17:09:10

Table 8: Number of activities performed by process participants as process-mined from organizational perspective

Employ-ees	Availability of staff (%)	ACT_1	ACT_2	ACT_8	ACT_12	ACT_5	ACT_6	ACT_3	ACT_4	ACT_11	ACT_13	ACT_9	ACT_14	ACT_10	ACT_7	**Sum_1**	Sum_1 without ACT: 2, 8, 12
ORIG.0	20	68	68											17		**153**	85
ORIG.1	20	2	18					14						1		**35**	17
ORIG.7	20	1	17					16								**34**	17
ORIG.5	20		10					10								**20**	10
ORIG.8	20		5					5								**10**	5
ORIG.18	20		1					1								**2**	1
ORIG.16	20		1					1								**2**	1
ORIG.2	20			3					39			36				**78**	75
ORIG.3	20			3					20			17				**40**	37
ORIG.9	20			4					15			12				**31**	27
ORIG.14	20			2					2							**4**	2
ORIG.10	20				1					1						**2**	1
ORIG.12	20				1					1						**2**	1
ORIG.15	20				1					1						**2**	1
ORIG.17	20				1					1						**2**	1
ORIG.11	20										3		3			**6**	6
ORIG.6	20					3	3									**6**	6
ORIG.13	20					1	1									**2**	2
ORIG.4	20														53	**53**	53
Sum_2	**-**	**71**	**120**	**12**	**4**	**4**	**4**	**47**	**76**	**4**	**3**	**65**	**3**	**18**	**53**	**484**	**348**

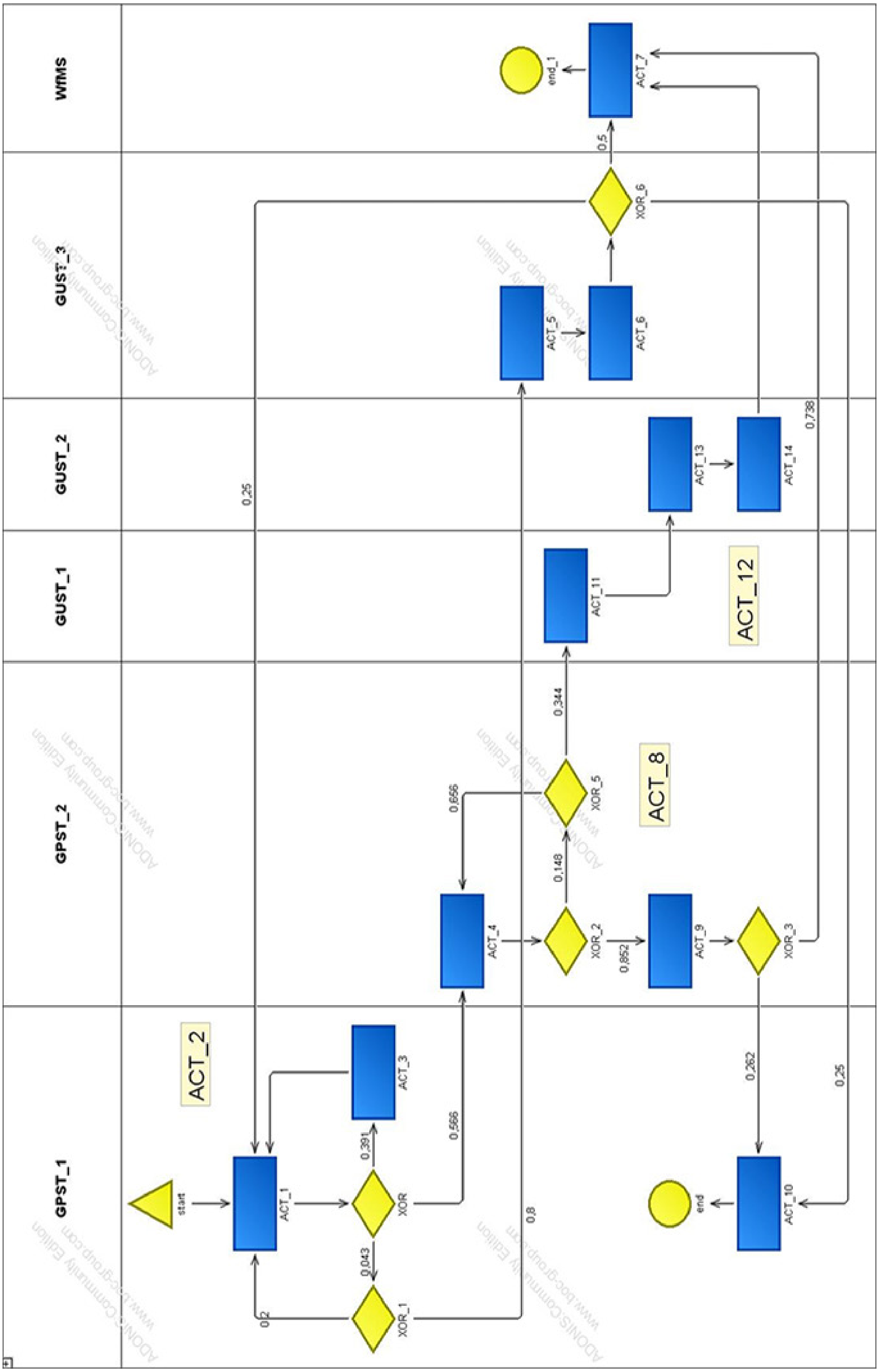

Figure 5. ADONIS model of Order Advice business process

Table 9: Process simulation results – quantitative participation of employees in the execution of individual activities

Employees	ACT_1	ACT_5	ACT_6	ACT_3	ACT_4	ACT_11	ACT_13	ACT_9	ACT_14	ACT_10	ACT_7	**Sum_3**	Total working time	Capacity
ORIG.0	43									9		**52**	00:000:01:51:48	0.004479
ORIG.1	32			11						7		**50**	00:000:03:05:41	0.007439
ORIG.7	44			8								**52**	00:000:03:08:56	0.007569
ORIG.5				10								**10**	00:000:01:33:10	0.003733
ORIG.8				7								**7**	00:000:01:05:13	0.002613
ORIG.18				8								**8**	00:000:01:14:32	0.002986
ORIG.16				3								**3**	00:000:00:27:57	0.00112
ORIG.2					21			21				**42**	01:120:00:47:39	7.309601
ORIG.3					18			22				**40**	01:121:03:53:10	7.336265
ORIG.9					16			22				**38**	01:113:01:01:56	7.175558
ORIG.14					20							**20**	00:083:04:32:20	1.607065
ORIG.12						1						**1**	00:000:00:26:22	0.001056
ORIG.17						2						**2**	00:000:00:52:44	0.002113
ORIG.11							3		3			**6**	00:048:03:29:54	0.931486
ORIG.6		2	3									**5**	00:031:05:05:47	0.608405
ORIG.13		2	1									**3**	00:010:04:53:09	0.204052
ORIG.4											55	**55**	00:000:00:00:00	0
Sum_4	**119**	**4**	**4**	**47**	**75**	**3**	**3**	**65**	**3**	**16**	**55**	**394**		

The first result of the computer simulation to be considered is the sum of the events that have "passed" through the entire model of the process and have reached the end of the diagram, i.e. steps *ACT_ 7* and *ACT_10* as depicted at Figure 5. Historically (Table 8), combined value of *Sum_2* for these activities is 71 (two highlighted cells containing values of 18 and 53 respectively) and coincides with the number of events recorded by the simulation algorithm (Table 9, two highlighted cells for *Sum_4* with values 16 and 55 respectively). The next outputs to be analyzed are total values in rows *Sum_2* (Table 8) and *Sum_4* (Table 9). Both reflect the number of times that a given activity was carried out by individual employees. For activities with identifiers 3-7, 9-10 and 13-14 assigned, values in both tables are very similar.

However, process mining issues require individual interpretation of results for *ACT_2*, *ACT_8*, *ACT_11* as well as *ACT_12*. It can be seen in Table 9 that the algorithm has registered 119 occurrences of *ACT_1*. ADONIS allows to implement the definition of the duration of the *ACT_2* as waiting time parameter for *ACT_1*. So, the result of 119 occurrences of *ACT_1* coincides with the actual number of *ACT_2* occurrences as shown in Table 8 (120). In case of *ACT_8* that had its execution time modeled as waiting time for *ACT_11*, one should not that *ACT_8* is in fact a "straight through" stage and the historically achieved values were distributed by the simulator among *ACT_4* and *ACT_11*. Number of *ACT_12* events was recorded by the simulator in the *ACT_11* cell.

Comparing values of *Sum_3* (Table 9) with *Sum_1* and *Sum_1 without ACT: 2, 8, 12* (Table 8) it is worth to notice that the couple of employees (*ORIG.10* and *ORIG.15*) were not occupied during the process simulation. This phenomenon – as well as related summary values – ought to be interpreted in relation to the distribution of work performed by the simulation algorithm that allocates incoming tasks randomly to resources being assigned to individual tasks. Assignment during simulation takes into account the *Availability of staff* (see Table 8). Most likely the value of 20% (as estimated by management staff across all process participants) does not accurately reflect the actual mechanism of division of labor. However, the degree of simulation results' conformity with historical data justifies analyzing workloads of individual employees of the telecommunications company.

The remaining two columns of Table 9 include simulation results regarding total working times of individual employees at various stages of the process as well as utilization ratios of employees. The latter was estimated based on three components: the number of working days per year declared (260 days), hours per working day (8 hours) and the percentage of availability (20%). If the value of this parameter is close to 1, then the employee is assigned optimal amount of tasks (see BOC Group, 2013). Analyzing the values calculated for individual employees, it can be stated that all employees from *GPST_1* team (Tables 4 and 9) are heavily over-loaded because the relevant *Capacity* values exceed 7. This is due to performing numerous *ACT_4* and *ACT_9* tasks, which translates into long workflows. In contrast, all *GPST_1* and *GUST_1* engineers are strongly under-loaded, because in their cases the values of *Capacity* are very low.

6 Discussion and limitations

In the paper, authors focused on combining approaches, leading to constructing business process model that reflects the actual behavior in the company. The research is based on the telecommunications company that continuously expands mobile networks and extends mobile services on one of the major European markets. While methods introduced proved to be applicable in real-life cases, a number of limitations were identified.

First of all, reliance of process mining on the precision of actual data may be considered a natural limitation. In the organization under investigation, logging infrastructures were faulty. Generally, if the business process management goes wrong (e.g. because of inadequate managers' involvement or lack of analysts' knowledge regarding BPM) business process activities can be executed outside the system. If the WfMS does not support process definitions and is out of optimizations, the employees initiate additional paths of communications, e.g. mails, phone calls, meetings, shared files. Activities which were not registered by WfMS cannot be taken into account for process mining analysis. This results in loss of vital information regarding processes and a decrease in the quality of analysis results (Weerdt et al., 2013). An "as-is" business process model elaborated with process mining algorithms reflects the behavior from the "system point of view", which in such case would differ from the actual process instances.

Secondly, process mining techniques still struggle with process implementation in a workflow system. Conducting research, authors came across faulty implementation of activities – a result of analysts modeling waiting times as independent tasks. Additionally, management staff did not put pressure on updating process definitions in WfMS, thus business and system process models differ.

It caused a number of issues while interpreting simulation results and necessitated additional meetings to resolve confusions. While process mining can provide novel and powerful ways to analyze business processes, academic research should focus even more on how process mining techniques can be improved (Weijters and Ribeiro, 2011) to discover information about processes and provide a view of how the processes are being executed.

Thanks to process mining algorithms providing information about staff involvement in the *Order Advice* business process, a fully equipped simulation model may be confronted with the historical execution of business activity. The overall results enable the simulation model to be taken into account as a reference model while planning modifications in the process. Having said that, a number of limitations regarding building the simulation process model as well as performing the simulation scenario should be pointed out:

1. Instance generator did not take seasonal fluctuations into account. In real-life, the number of initiated instances increased/decreased seasonally in a specific place and time – e.g. in the summertime mobile network capacity should be extended in the seaside locations.
2. Data presented in Table 6 may slightly differ from the actual data – e.g. the availability of staff might be tuned-in should all the processes and their participants be analyzed.
3. Number of process instances available for analysis was restricted.
4. Activity execution time is an average value estimated by ProM; the value at hand reflects timestamps recorded by WfMS while clicking start/stop buttons that may differ slightly from actual processing time.
5. Human resources were modeled in a simplified manner (Van der Aalst, 2010). In reality, different people can do the same work – but in a different style. Route-cause analysis of differentiation may be conducted: people do not work at a constant speed and they tend to divide work into multiple parts. Moreover, employees are usually involved in simultaneous business processes, so they accumulate tasks from different processes and perform them at the same time. In effect, it makes it challenging to precisely assign human resources to the activities in simulation models. This problem still requires ongoing research, still it is noteworthy that over 40 resource patterns were identified to describe the functionality of resource allocation mechanisms (Russell et al., 2005) and few of these patterns are supported by business process simulation tools presently available.

The capacity analysis algorithm estimate “as-is” state of business process execution. By applying numerous additional simulations algorithms (e.g. workflow analysis) and adjusting the parameters of the model, a set of implementable process variants can be developed. It is also possible to estimate workloads and identify bottlenecks and deadlocks. The aforementioned actions lead to the development of new business process definitions that – after being implemented within the structure of the company – shall improve its operation. As a result, the optimized model makes a strong basis for the workflow system. Adapting this redesigned process definition to the workflow engine leads to the organization being run in accordance with an elaborated and validated computer model.

7 Conclusions

Business organizations’ competiveness is determined to a large extent by monitoring processes and carrying out simulations/optimization in a rapidly changing business environment. Process management is based on decisions about the need to change and proposals for improving processes which – prior to implementation in business practice – should be simulated within dedicated environments. Performing various business scenarios requires simulation model that is digitalized and powered with data which reflecting not the analyst’s intuition but a real-life operation of the company.

BPS_2 (see Figure 1) is not a popular approach for process reengineering and improvement yet. Traditional business process reengineering (Hammer and Champy, 1993) focuses mostly on clarification as well as rationalizing processes/resources rather than producing implementable and computational models. While some organizations implement *BPS_1* approach for new processes, such organizations tend not to push forward the Deming cycle; and so the analytical stage (*Check*) is reduced to basic process investigations rather than deep process analysis. Difficulties with collecting data for *BPS_2* constitute one of the possible reasons for this. Data extraction requires adopting both process mining techniques and human source-related information sources.

Research conducted lived to see the feedback from the management of telecommunication company. Mainly, process mining results were discussed: discovered process paths as well as human resource allocation to the individual activities. Time parameters of activities raised attention as well. During post-research meetings considerable amount of out-of-the-paper-scope results were verified. For instance, evidence was provided that WfMS allows for some undesirable behavior like ignoring tasks or violating business rules. Flow of work between process participants was discussed in detail as well. Generally, research had encouraged managers to take a closer look while designing and improving processes, as well as to improve their decision-making while mapping processes into WfMS.

Simulation-oriented part of research was verified with staff as well. While multi-step process of achieving simulation-ready models proved to be a challenge for management staff, capacity analysis output generated an interest in simulation algorithms. Various business scenario simulations with other ADONIS algorithms are under consideration.

Ongoing research is advancing in multiple directions. First of all, additional case studies in various industrial domains are carried out. Process mining analysis is the prime subject, focused on discovering information regarding processes and powering simulation models. Other mining tools (e.g. DISCO) are used and evaluated. Secondly, other simulation algorithms/tools to evaluate simulation models and compare simulation results with historical data are evaluated.

Especially, authors attempt to elaborate new factors that help to assess the quality of the simulation model. Additionally, research aimed at refining the process generation mechanism to better (closer to reality) reflect process instances in a simulation model is carried out. Finally, running process simulation not only to assess the simulation model but to predict future behavior in the company as well is a research direction under investigation. The latter concerns primarily workloads and possibilities of executing some processes in a limited period of time.

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